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EARTH RESOURCES SURVEY PROGRAM

TECHNICAL LETTER NASA-16

GEOLOGICAL EVALUATION OF RADAR IMAGERY, OREGON COAST

By

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and

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U. S. Geological Survey
Menlo Park, California

May 1966

Prepared by the Geological Survey for the
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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 16
May 1966

Dr. Peter C. Badgley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith are 3 copies of:

TECHNICAL LETTER NASA-16

GEOLOGICAL EVALUATION OF RADAR IMAGERY

OREGON COAST*

by

Parke D. Snavely, Jr.**

and

Holly C. Wagner**

Sincerely yours,

William A. Fischer
Research Coordinator for
USGS/NASA Natural Resources Program

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Menlo Park, California

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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not be quoted without permission

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Parke D. Snavely, Jr., and Holly C. Wagner

Abstract

Radar imagery of a coastal strip extending from the Columbia River almost to the California border was obtained with a high frequency side-looking radar. A qualitative evaluation indicates that radar imagery is a potentially useful tool for geologic mapping in regions where bed-rock is masked by dense vegetation. The radar sensor effectively "defoliated" Coastal Oregon, thus greatly enhancing the topographic and tonal expressions of certain Tertiary rock units. Faults and lineaments that cannot be identified on conventional black and white photography can be recognized.

Preliminary interpretations indicate that radar returns in this area are dependent principally upon density and water content of the rock units. The tonal renditions of certain Tertiary units are distinctive. Miocene basalt flows show the highest returns (lightest tones), sandstones give intermediate tones, and marine mudstones have the lowest radar returns of any of the Tertiary rocks. The juxtaposition of these contrasting tones and differences in topographic expression defines the positions of depositional and fault contacts.

Introduction

Radar imagery of a coastal strip approximately 10 miles wide extending southward from the mouth of the Columbia River almost to the California border was flown at the request of the U.S. Geological Survey on October 25, 1965. Two images were obtained with high frequency side-looking radar that was operated in a polarizing mode. One image was horizontally polarized both in transmission and reception; the other was produced from a vertically polarized component of the return signal that had been transmitted horizontally polarized. Two strips were flown, one with a flight path traveling from south to north along the coastline and the other about 10 miles east traveling from north to south. These two flight lines are specified by the Geological Survey, as they traverse a wide variety of rock types of Mesozoic and Tertiary age. Thick sequences of interbedded eugeosynclinal volcanic and sedimentary rocks of Tertiary age underlie the northern three-fourths of the strip; the terrain in the southern one-fourth is composed of structurally complex sedimentary, igneous, and metamorphic rocks of Mesozoic age (fig. 1). The north-directed flight resulted in high resolution, continuous radar imagery throughout the flight line, but a storm at the time of the southward flight rendered useless all except small segments of the imagery in the Astoria and Coos Bay areas.

Inasmuch as the bedrock geology in coastal Oregon is obscured by a dense growth of coniferous forests, heavy brush, and thick soil, it was hoped that the electromagnetic radiation would penetrate at least part of this cover so that the trends of major structural elements and the distribution of principal lithologic units would be enhanced. The imagery briefly reported upon here, demonstrates the effective penetration of radar through dense vegetation, as details of topography obscured on conventional photographs stand out on the radar imagery.

This report is concerned primarily with a geologic evaluation of the radar imagery in the northern part of the coastal flight strip, for geological studies are currently under way there by the senior author. Vertical black and white photography from several sources and at various scales as well as some low-angle oblique photos are available in most of this area for comparison with the radar imagery. An evaluation of the southern (pre-Tertiary) portion of the strip is being made by Geological Survey geologists familiar with the geology in the Klamath Mountains area.

Radar Imagery - General Comments

Scale variations

Measurement between known points on the radar imagery indicates that the scale varies significantly in both north-south and east-west directions. At the northern end of the flight line the north-south scale averages about 1:188,000; east-west it is 1:192,000. In the southern part near Coos Bay the north-south scale averages 1:205,000; east-west it is 1:201,000. Near the center of the flight (Newport area) the scales average: north-south 1:170,000; east-west 1:195,000.

Image distortion

Imagery directly below the plane is greatly distorted, producing a simulated horizon effect when viewed perpendicular to the line of flight and toward the ocean (fig. 2). The general perspective is similar to that obtained if the coast line were viewed from a point about 10 miles inland and from a height of about 3,000 feet. The narrow basalt headland at Yaquina Head is greatly foreshortened, and broader capes, such as Cape Foulweather, appear to block the coast line from view.

Resolution of cultural features

Many cultural objects show with remarkable clarity on the radar imagery. Linear features, such as concrete bridges, long piers and rows of pilings, and breakwaters and jetties show best, but fishing boats (some possibly only 20 feet in length), houses (where roofs contrast strongly with surroundings), and even power-line footings (in water) show well.

Airstrips show as dark strips of distinctive shape (fig. 3), but highways and secondary roads in general show poorly. Although parts of some main highways can be seen on the radar images as dark or light lines, other parts do not show at all. It is surprising that the extensive networks of logging roads that are so apparent on conventional photographs, show in the images in only a few places. This absence may reflect the fact that most of the road metal used on the logging roads corresponds closely to the surrounding bedrock. Highways with roadcuts show well locally, probably owing to the steepness of the roadcut faces. Power lines in places show well on the imagery (fig. 3), perhaps due to radar back scatter off the power lines themselves; but many do not show at all.

Resolution of topographic features

Large scale topographic features, although geometrically distorted, are clearly displayed on the radar images. Even more impressive, however, is the rendition of small topographic features. This is due, presumably, to the ability of the electromagnetic radiation to penetrate through vegetation and, in essence, to "defoliate" the thick cover of trees and brush that normally obscures the finer details of the topography. Proof that this "defoliation" phenomenon is essentially complete is shown by the absence of tonal differences between logged-off and timber-covered areas on the radar imagery, whereas on conventional photographs the logged-off areas appear as nearly white patches surrounded by dark areas of timber.

In these images of Coastal Oregon we estimate that topographic detail shown on the radar imagery is roughly twice that shown on conventional photographs (fig. 4). The intricate network of small streams and drainages shows in great detail on the radar image, and such imagery would very likely make possible the addition of much detail in the preparation of topographic maps.

As is the case on conventional photographs, strong shadows on radar images, although they emphasize the topography, tend to obscure the drainage systems where shadows are particularly dark. Shadows the images of the north-directed flight appear as would shadows on conventional photographs if taken at mid-afternoon.

Effect of vertical polarization

The vertically polarized image is less useful than the horizontally polarized image because vertical polarization produces less tonal contrast between rock units or cultural features. The principal advantage of the vertically polarized image was that the vertical polarization penetrated thin clouds and produced ground imagery in a few areas where thick clouds obscured the ground on the plane-polarized image.

Radar Imagery - Geologic Applications

Tonal rendition of rock units

Tonal rendition (shades of gray) on the radar image is apparently affected by three factors: (1) rock density and composition, (2) surface roughness of rock unit, and (3) water content of unit. In order to show the relationship between tonal rendition and geology, geologic sketch maps have been drawn directly from the radar imagery in several selected areas. The assignment of tonal difference to specific lithologic units is based upon a personal knowledge of the regional geology of the Oregon Coast Range. Undoubtedly geologic knowledge influenced the positioning of geologic contacts in a few places.

Rocks of high density and surface roughness generally underlie the lightest colored areas. Rough-surfaced middle Miocene basalt (density 2.9), for example, forms the light-colored headland (Cape Lookout) in figure 3. Rocks of low density and/or high water content, such as alluvial materials and very fine grained sedimentary rocks, generally have the darkest tones. The Quaternary alluvium and terrace materials (Qal and Qt) and the late Eocene marine mudstones (Tem) of figure 2 have characteristic dark tones and are readily separated from the carbonate-cemented, higher-density middle Eocene sandstones of the Tyee Formation (Tt) which appear much lighter in tone and bolder in relief. Such tonal contrasts make it possible to delimit many formational boundaries in the Tertiary eugeosynclinal accumulation of basalts, mudstones, and sandstones.

Recognition of linear structural features

The sharp juxtaposition of contrasting tones and differences in topographic expression make possible locally the accurate identification of the traces of a set of northwest-trending faults (fig. 2).

The previously unrecognized nearly north-south trending lineament west of the center of figure 2 is conspicuous on the radar image. This lineament is interpreted as a fault that forms a general boundary between tuffaceous sandstone and siltstone of Oligocene and Miocene age on the west and upper Eocene siltstone on the east. It should be noted, however, that the four formational units included in the Oligocene and Miocene sequence (Tmom on fig. 2) cannot be differentiated on the radar imagery.

About 10 miles south of Astoria in extreme northwestern Oregon an arcuate structure, not recognized heretofore, is very apparent on the radar image (fig. 5). The northern part the arcuate structure has a hook-shaped form and is occupied by a thick sill of fine-grained gabbro of Miocene age. The sill cuts upper Eocene(?) sediments and dips steeply northeastward where breached by Youngs River. Although a detailed geologic map is not available for the area, the sill appears in the radar image to follow a pre-existing structure in the northern part of the arc. Farther south the western part of the arcuate structure seems to control the drainage of Lewis and Clark Creek. Still farther to the southeast the structure apparently cuts Miocene basalt breccias and flows. The eastern half of the arc, if present, is not covered by the imagery. Because of its arcuate shape and the large volume of Miocene pillow flows and breccias in this area, it is speculated that this structure is of volcano-tectonic origin.

The contact between Tertiary bedrock and flat-lying, uplifted marine terrace sands of late Pleistocene age along the coast can be easily drawn, as can the contact between valley alluvium and bedrock (figs. 2, 3, 5, and 6). Long narrow parallel ridges, which probably are raised offshore bars, are readily apparent in the Quaternary sediments on figure 5. In the Tenmile Lakes area south of the Umpqua River (fig. 6) an extensive belt along the coast is covered by dune sands. Most of this belt has the same dark tones as the water in the lakes immediately to the east (fig. 6), indicating that the sands probably are water saturated. The small light-colored arcuate features within the dark belt are the tops of large dune ridges which presumably are dry sand. The narrow light-gray strip of beach sand, between the dune belt and the ocean, probably also is moisture free in its upper part.

Conclusions

This qualitative evaluation indicates that side-looking radar imagery is a potentially useful tool for geologic mapping in regions where the bedrock is masked by dense vegetation. The radar sensor has effectively "defoliated" Coastal Oregon, thus greatly enhancing the topographic and tonal expressions of various Tertiary rock units. Faults and lineaments that cannot be readily identified on conventional black and white photography can be recognized.

These preliminary interpretations indicate that a general correlation exists between rock density and radar reflectivity. The water content of porous, uniformly fine-grained sediments also greatly affects image tones. Areas underlain by dense basalt of middle Miocene age have the highest radar returns (lightest shades of gray); Eocene basalts give somewhat lower returns owing to numerous tuff interbeds in these more altered flows. Middle Eocene carbonate-cemented sandstone (Tyee Formation) gives higher radar returns than Oligocene silty tuffaceous sandstones. Eocene marine shales give low radar returns (medium-gray tone); and alluvium and marine terrace deposits with high moisture content have even darker tones. Water-saturated dune sands have the lowest tonal values of the lithologic units and appear the same as dark bodies of water.

Inasmuch as the westernmost extensions of several major faults are apparent on the coastal strip of radar imagery, it is anticipated these faults and others could be recognized elsewhere in the timber-covered Oregon Coast Range and the regional tectonic framework could be greatly improved if synoptic radar imagery was available for the entire Coast Range.

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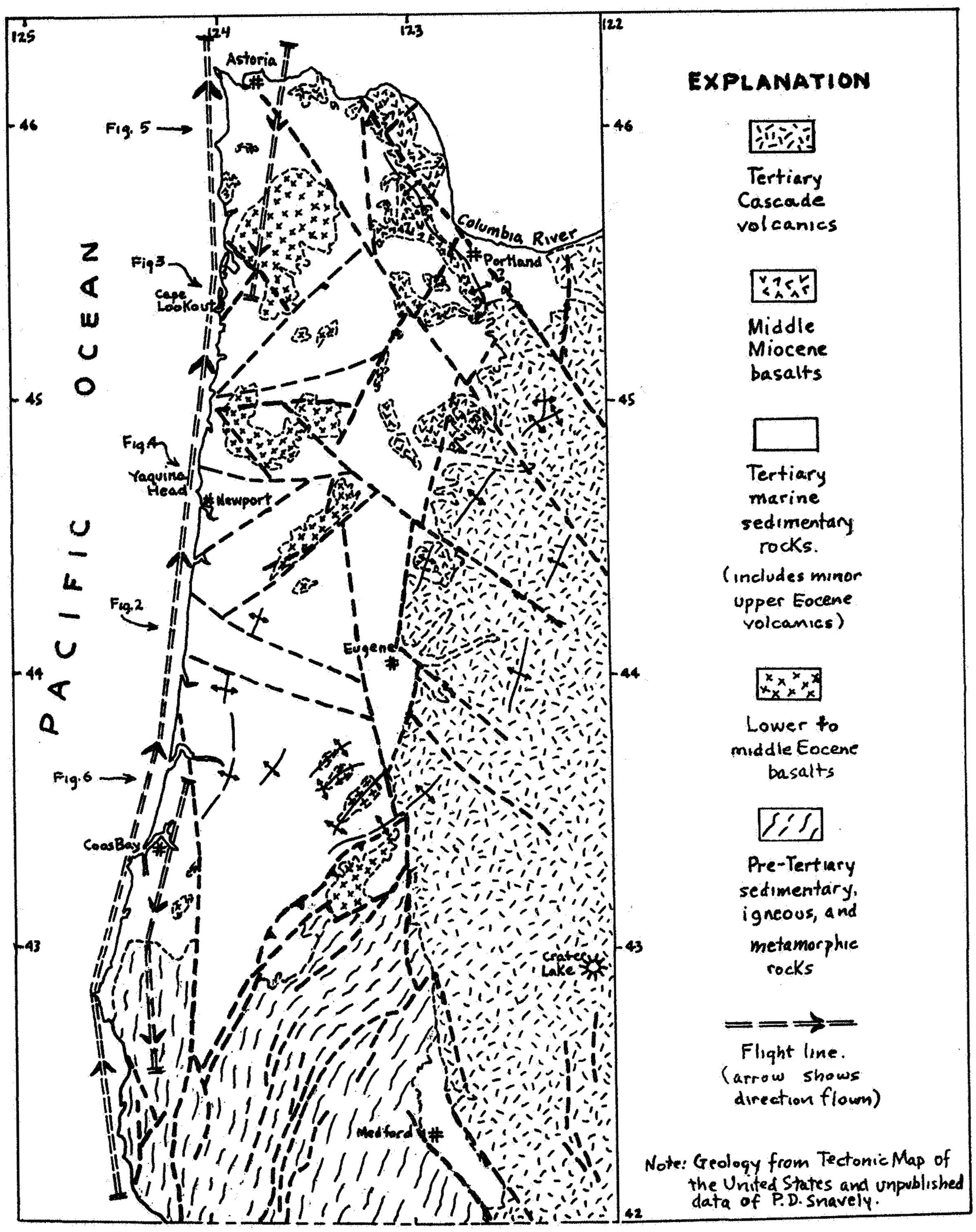
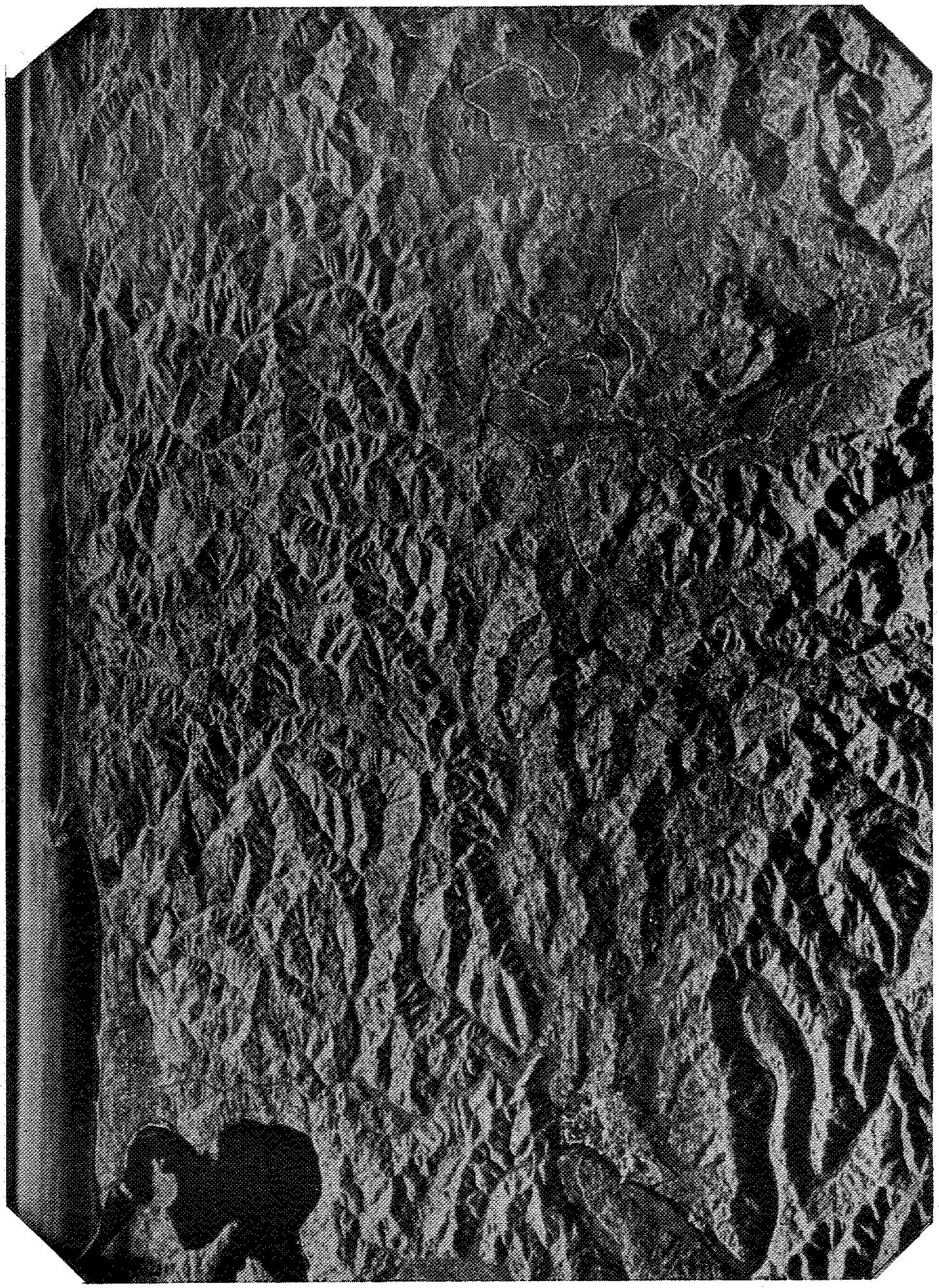


Figure 1. Generalized geologic map of western Oregon showing overflight lines for radar imagery and general locations of figures referred to in text.



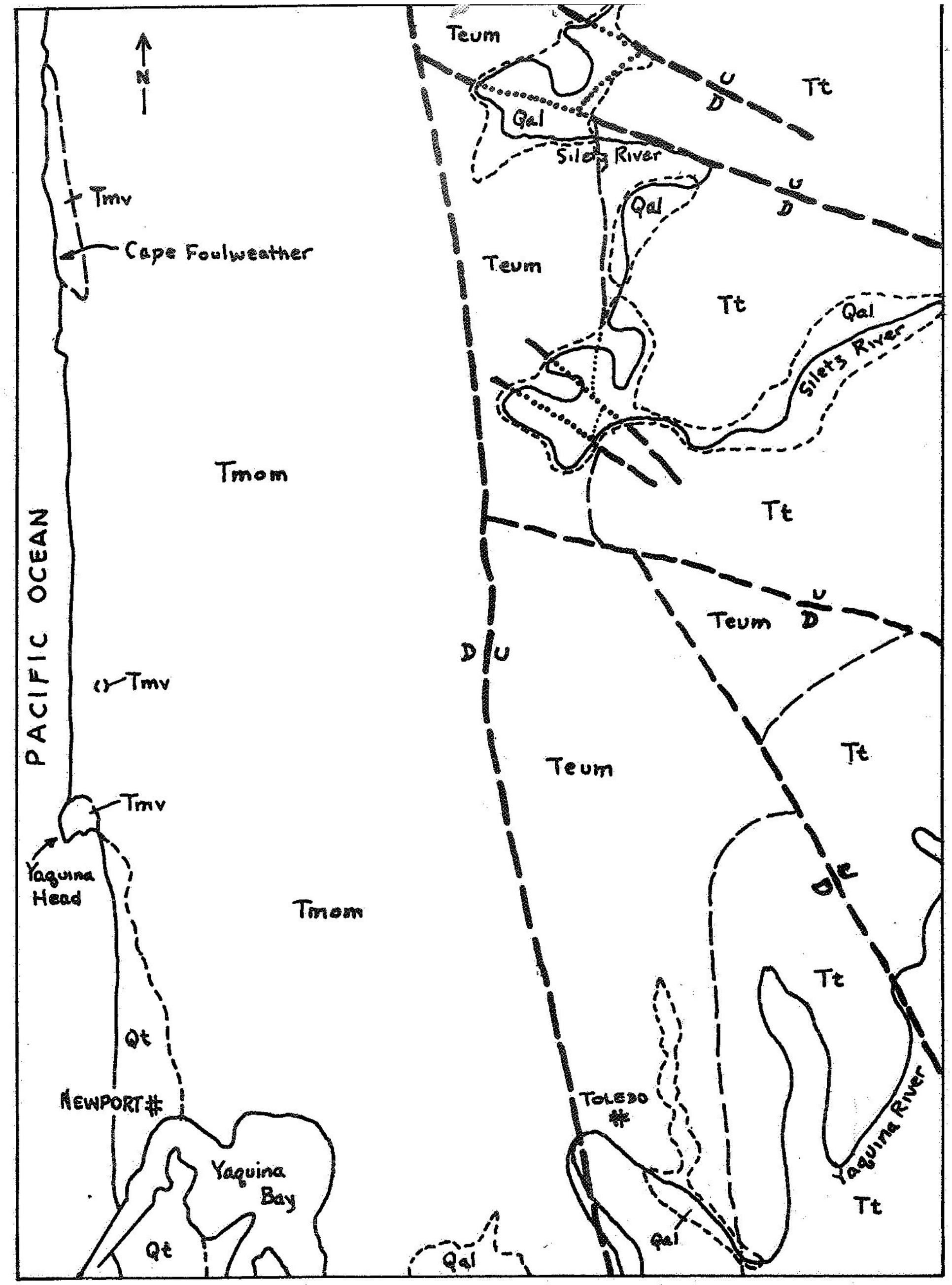


Figure 2. Radar imagery and radar geological sketch map of the Newport area showing the tonal contrast between undifferentiated upper Eocene mudstone and siltstone units (Teum) and middle Eocene sandstone of the Tyee Formation (Tt) to the east and undifferentiated upper Tertiary tuffaceous sandstones (Tmom) to the west. Also indicated are Miocene volcanics (Tmv), Quaternary terrace deposits (Qt), and valley alluvium (Qal). Heavy dashed lines are faults.

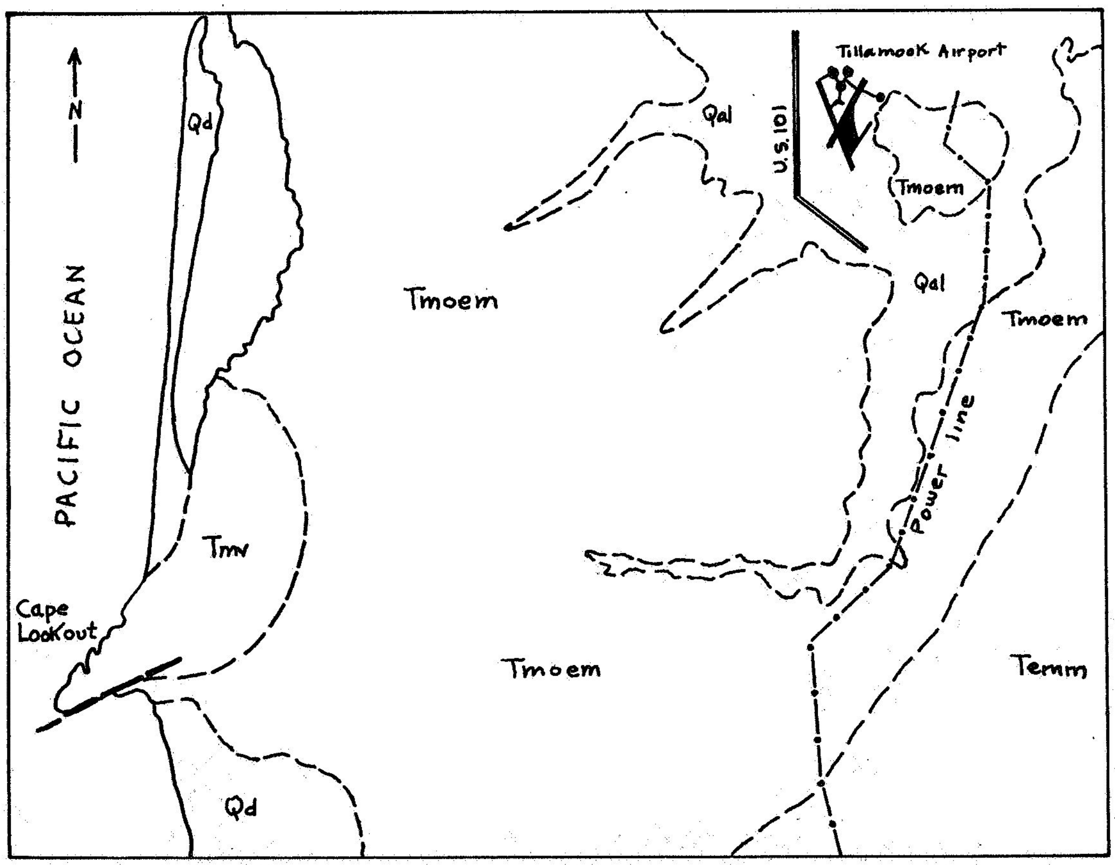
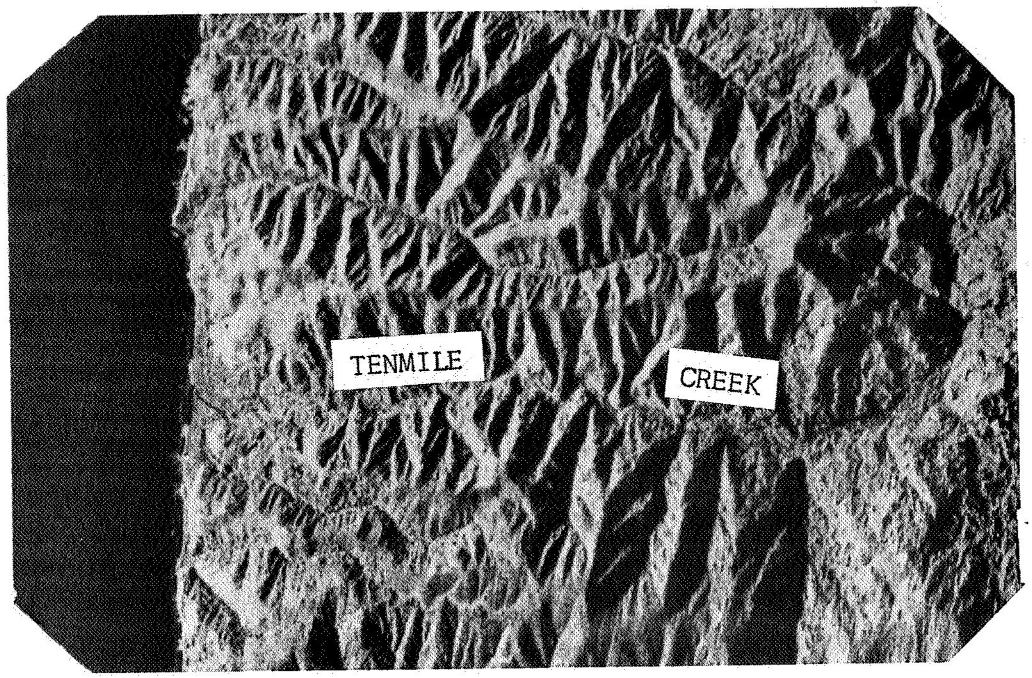


Figure 3. Radar imagery and radar geological sketch map of the Cape Lookout area. Miocene volcanics (Tmv), middle Eocene marine sedimentary rocks (Temm), and intervening Miocene, Oligocene, and uppermost Eocene sedimentary rocks (Tmoem); also dune sands (Qd) and alluvium (Qal).



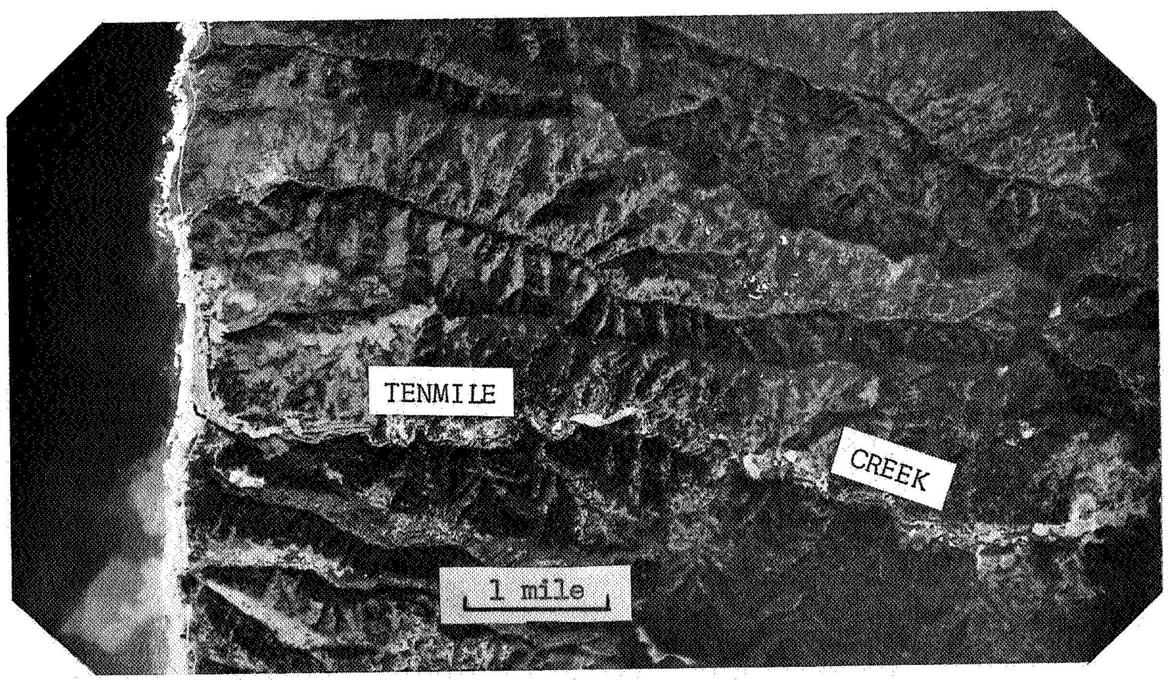


Figure 4. Comparison between photographically enlarged radar imagery (above) and conventional photography (below) in the Tenmile Creek area of coastal Oregon.

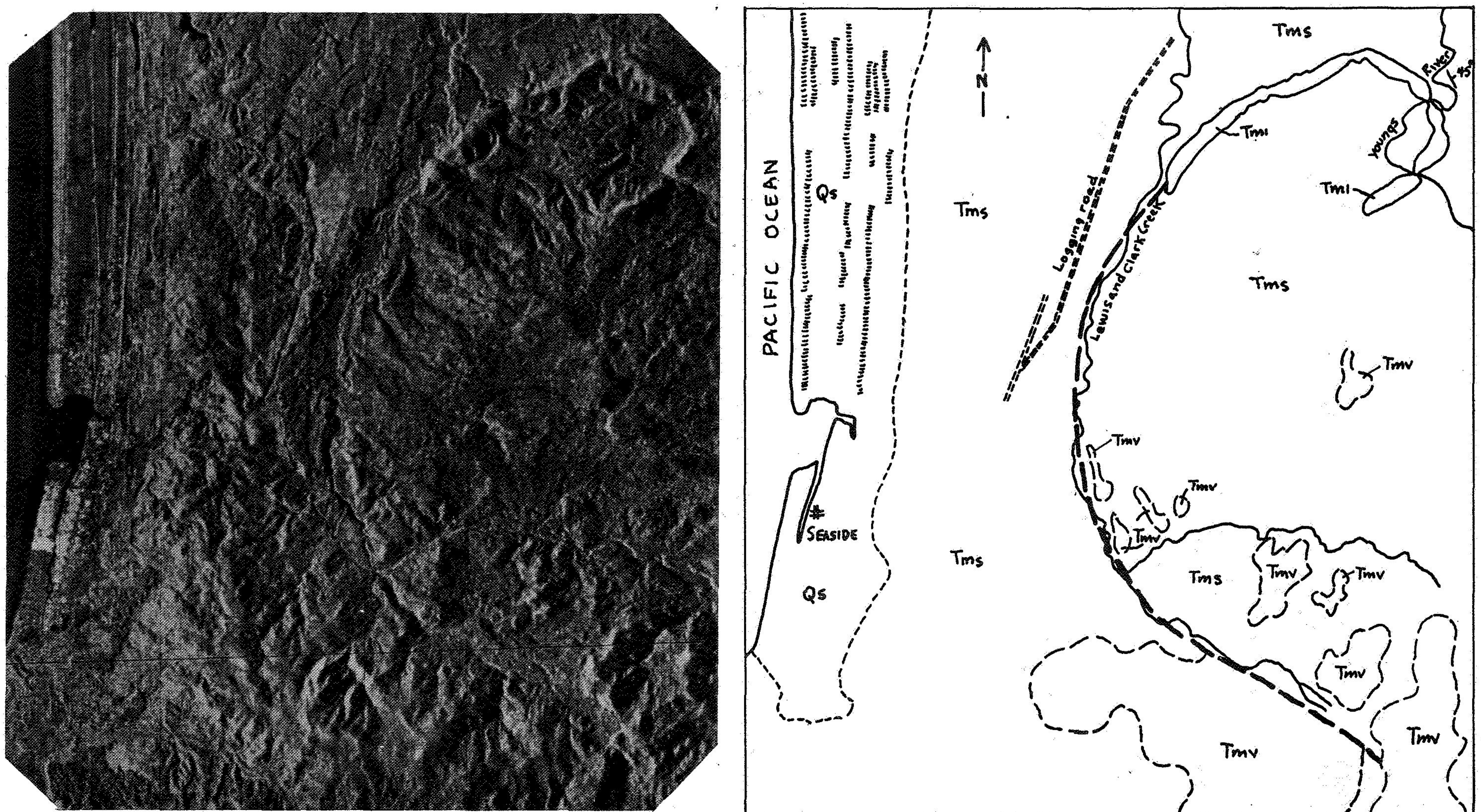
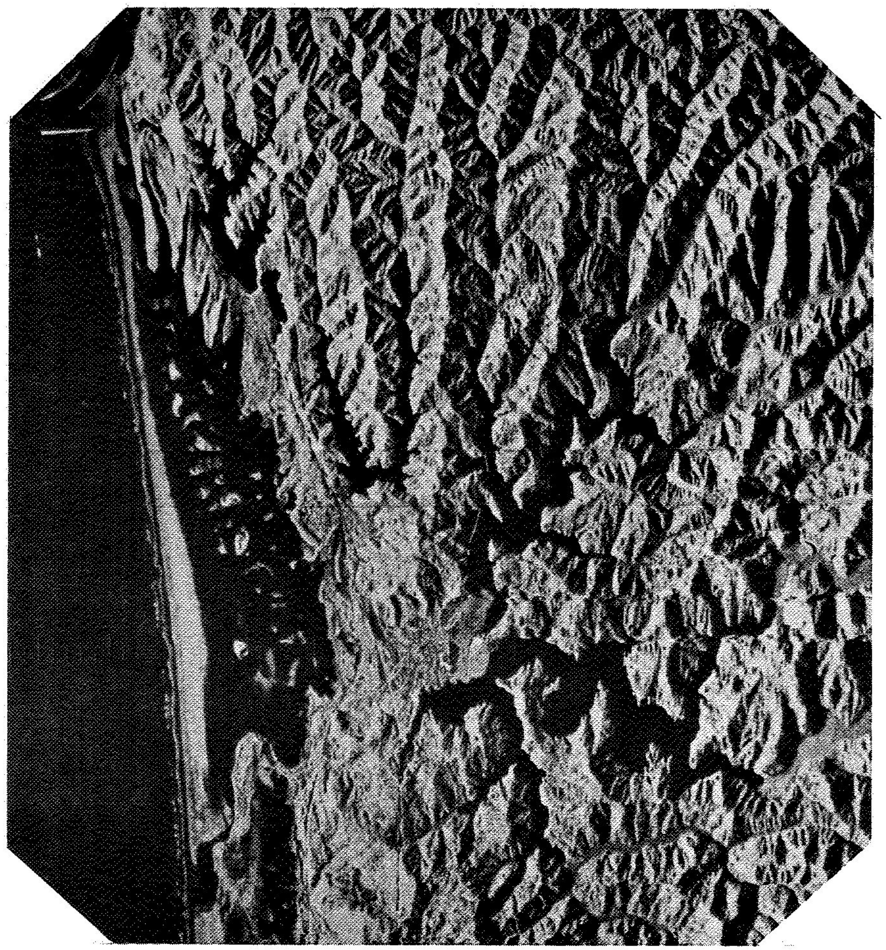


Figure 5. Radar imagery and radar geological sketch map of the Seaside area showing a major arcuate structure that is convex to the west. Miocene gabbroic intrusive (Tmi), Miocene volcanics (Tmv), Miocene sedimentary rocks (Tms), and Quaternary sediments (Qs).



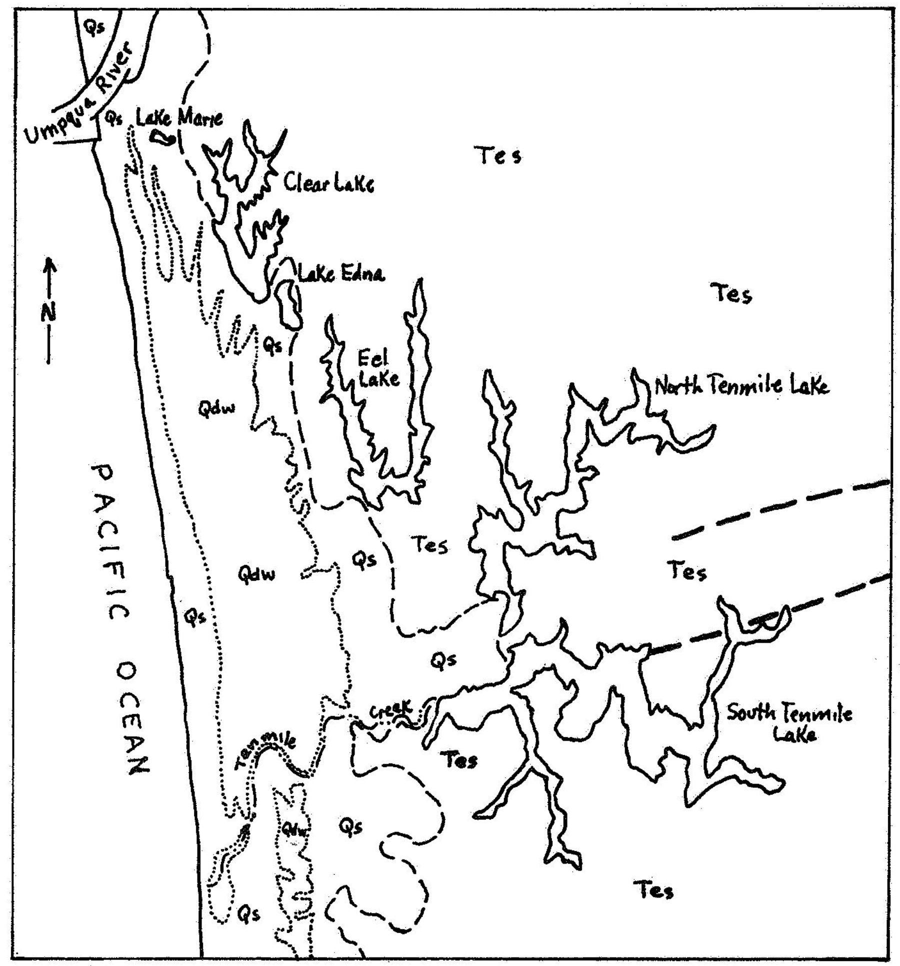


Figure 6. Radar imagery and radar geological sketch map of the Tenmile Lakes area showing Eocene sandstone (Tes), stabilized dune sands, beach sands, and alluvium (Qs), and water-saturated dunes (Qdw).